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WAVELENGTH CONVERTER PLACEMENT IN OPTICAL NETWORKS USING WAVELENGTH CONVERSION ARCHITECTURES

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Abstract

Sparse wavelength conversion and wavelength assignment (RWA) algorithms square measure the 2 key factors in up the interference performance in wavelength-routed all-optical networks. it's been shown that the best placement of a restricted range of wavelength converters in AN capricious mesh network is AN NP-complete downside. There are numerous heuristic algorithms planned within the literature, during which most of them assume that a static routing and random-wavelength assignment RWA algorithmic rule is used. However, the prevailing work shows that fixed-alternate routing and dynamic routing RWA algorithms can do far better interference performance. Our study additional demonstrates that the wavelength convertor placement and RWA algorithmic rules square measure closely connected within the sense that a well-designed wavelength convertor placement mechanism for a specific RWA algorithmic rule may not work well with a unique RWA algorithm. Therefore, the wavelength convertor placement and also the RWA have to be compelled to be thought-about together. the target of this paper is to research the wavelength convertor placement downside beneath the fixed-alternate routing (FAR) algorithmic rule and least-loaded routing (LLR) algorithmic rule. beneath the so much algorithmic rule, we tend to propose a heuristic algorithmic rule known as minimum interference chance 1st for wavelength convertor placement. beneath the LLR algorithmic rule, we tend to propose another heuristic algorithmic rule known as weighted most section length. the target of the convertor placement algorithms is to attenuate the general interference chance. intensive simulation studies are dispensed over 3 typical mesh networks, as well as the 14-node NSFNET, 19-node EON, and 38-node CTNET. we tend to observe that the planned algorithms not solely outstrip existing wavelength convertor placement algorithms by an oversized margin, however they can also attain virtually constant performance compared with full wavelength conversion beneath constant RWA algorithmic rule.

Introduction

All-optical networks using wavelength-division multiplexing (WDM) and wavelength routing observe area unit thought-about as promising candidates for backbones to fulfil ever-increasing information measure needs for advanced telecommunication services. In wavelength routed optical networks, communication between finish nodes is achieved through all-optical connections known as the light paths. If network nodes don't seem to be equipped with wavelength converters (WCs), every light path has got to be assigned a novel wavelength over all physical links on the chosen route, that is thought because the wavelength continuity constraint.

Due to restricted out their wavelengths, the wavelength continuity constraint sometimes leads to exaggerated network obstruction probability. it's been shown that application of WCs at network nodes has a very important role to avoid the wavelength conflicts on the trail and consequently scale back the general network obstruction probability. If all network nodes area unit equipped with WCs, it's spoken as a network with full wavelength conversion. However, considering that WCs area unit still extremely high-priced parts, it's going to not be economical to implement the converters all told nodes. what is more, it's been shown that if just some nodes area unit equipped with wavelength converters, the network obstruction probability might be nearly to it with full wavelength conversion. Therefore, an additional realistic situation could be a network with distributed wavelength conversion, which implies solely a sub-set of network nodes have the aptitude of wavelength conversion. The central question that arises in such case is that the following: wherever to position a restricted variety of WCs so as to achieve minimum obstruction probability? There are a unit varied approaches to resolve the WCP drawback in distributed wavelength conversion optical networks, that might be classified into precise, heuristic and metaheuristic approaches.

The thoroughgoing Search (ES) is that the simplest precise methodology to search out best placement of a given variety of wavelength converters. Such approach needs to get (analytically or by simulations) the obstruction probability performance for all doable mixtures to position given variety of wavelength converters and at the moment to pick the location with minimum obstruction probability. However, because of high process complexness and prohibitor time consumption to search out the best answer, metaheuristic tools have to be compelled to be accustomed solve the matter expeditiously in realistic size networks. So far, this drawback has been solved by application of various metaheuristic approaches like Genetic Algorithms (GA), Tabu Search (TS), Particle Swarm improvement (PSO), Differential Evolution (DE), pismire Colony improvement (ACO) etc. during this paper, we have a tendency to introduce the appliance of Bee Colony improvement (BCO) approach to resolve the WCP drawback and compare the projected BCO-WCP algorithmic rule to another approaches, like metal likewise as PSO and DE metaheuristics. To the simplest of our data, this paper is that the 1st application of BCO approach to resolve the WCs placement drawback.

Various studies tested that the BCO algorithmic rule could be a quick, strong and economical world search improvement tool, which might manufacture prime quality answer with tiny process complexness. Our goal here is to demonstrate the effectiveness and potency of the BCO approach whereas resolution the thought-about WCP drawback. it'll be shown that the recommended BCO-WCP algorithmic rule isn't solely able to offer prime quality (even optimal) answer, however vastly outperforms the potency of metal approach and achieves even higher potency compared to similar metaheuristic approaches, like DE and PSO.

Literature Review

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Wavelength-Routed all-optical networks area unit thought of to be candidates for consecutive generation wide-area backbone networks. In such networks, wavelength conversion (or translation) plays a vital role in rising the fiber link utilization and reducing the decision block probability. Since the wavelength converters area unit still terribly costly today, a lot of analysis work focuses on distributed wavelength conversion, which implies that solely a part of the network nodes has the potential of wavelength conversion, whereas others haven't any conversion capability. If all the network nodes area unit capable of wavelength conversion, this is often cited as full wavelength conversion [1].

It has been shown therein, by victimization distributed wavelength conversion, a comparatively tiny variety of converters can do satisfactory performance. However, the matter of wavelength device placement wasn't thought of. That is, given a net- work topology, an exact variety of wavelength converters, and traffic statistics, however will the wavelength converters be placed into the network so as to reduce the block prob- ability? Sometimes, this is often self-addressed as a separate issue that's solved by device placement algorithms. The algorithms for optimum device placement in straightforward topologies, like bus and ring, are provided in. However, optimum device placement for a lot of realistic topologies like impulsive mesh is taken into account to be terribly laborious [2]. Hence, variety of heuristic algorithms is planned. All of them assume that the static routing and random wavelength assignment (RWA) algorithmic rule is used.

Nevertheless, the literature results show that the block possibilities of wavelength-routed networks area unit heavily addicted to the RWA algorithms. Our studies additionally demonstrate that a well-designed wavelength device placement mechanism for the static RWA algorithmic rule doesn't work well below a distinct RWA algorithmic rule. Therefore, we tend to argue that wavelength device placement and RWA algorithms ought to be thought of collectively. During this paper, we tend to investigate the matter of wavelength device placement below 2 RWA algorithms, each of that have exhibited that higher block performance may be obtained. the primary one is that the fixed-alternate routing and first-fit wavelength assignment (FAR-FF RWA) algorithmic rule. The second is that the least-loaded routing and first-fit wavelength assignment (LLR-FF RWA) algorithmic rule. The way algorithmic rule has been shown to shell the static routing algorithmic rule considerably. The LLR algorithmic rule may be a normally used dynamic routing algorithmic rule, which may sometimes bring home the bacon higher performance than the way algorithmic rule, at the expense of longer setup delays and better management overheads. The FF wavelength assignment algorithmic rule can do virtually an equivalent performance because the most-used wavelength assignment algorithmic rule and is incredibly straightforward for implementation. For the FAR-FF RWA algorithmic rule, we tend to 1st gift associate degree approximate analytical model which will derive the block probability of wavelength-routed all-optical networks that use the way algorithmic rule. supported the analytical model, we tend to propose a heuristic algorithmic rule, referred to as minimum block probability 1st (MBPF), for putting a restricted variety of wavelength converters in associate degree impulsive mesh network. For the LLR-FF RWA algorithmic rule, we tend to propose another economical heuristic device placement algorithmic rule, referred to as the weighted most phase length (WMSL) algorithmic rule [3].

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In our network model, the association calls gain the network consistent with a Poisson method and also the association holding time is exponentially distributed. The planned MBPF associate degreed WMSL algorithms will place any variety of wavelength converters in an impulsive mesh network expeditiously. we tend to 1st measure the profit associate degreed significance of distributed wavelength conversion through simulations on an 8-node ring network and a 25-node mesh-torus network. After that, we tend to measure the performance of the MBPF and WMSL algorithms victimization intensive simulations on 3 typical mesh network topologies, as well as 14-node NSFNET, 19-node European optical network (EON), and 38-node China medium network (CTNET). The simulation results show that, with the suitable RWA algorithms, our heuristic device placement algorithms shell existing algorithms considerably. Moreover, our heuristic algorithmic rules for a restricted variety of wavelength converters can do virtually an equivalent performance examination with full wavelength conversion below an equivalent RWA algorithm [4].

Solution for the baseline methods for assignment of calls of RWA: BCO Metaheuristic

BCO is computing approach galvanized by hunt the behaviour of natural bees. it absolutely was originally planned by Teodorović and Lučić to unravel the bagman and vehicle routing issues. So far, BCO has been with success accustomed solve numerous improvement issues, as well as those associated with optical network style, like the routing and wavelength assignment (RWA) drawback and light path-scheduling drawback. A comprehensive survey of varied BCO engineering applications may be found in.

BCO is strong population primarily based random random-search technique, within which artificial bees explore the search house searching for best resolution. every bee in population generates one resolution to the thought-about drawback. throughout the looking procedure, bees iteratively modify their individual solutions generating in such approach new possible solutions. so as to search out promising solutions bees, perform cooperative activities by exchanging the data regarding the standard of individual solutions. during this approach, bees' bit by bit attempt to raised solutions and slowly run-away worse solutions.

There are 2 varieties of BCO algorithm: constructive and improvement versions. the primary approach is predicated on constructive steps within which bees ranging from AN empty initial resolution build their partial solutions incrementally throughout the search method. within the second approach, bees begin from complete initial solutions and modify them through the search method so as to get the most effective potential race murder. The BCO-WCP formula planned during this paper is predicated on the second approach.

At the start of search method, all artificial bees begin their flights from the hive. the quantity of bees, B engaged within the search method is per advance. throughout the search method, bees modify and valuate their individual solutions by steps. every step consists of 2 phases: forward and backward passes. throughout every passing play, each bee makes modifications of its current resolution. AN illustration of 1 (first) forward and backward pass is shown by Fig.1.

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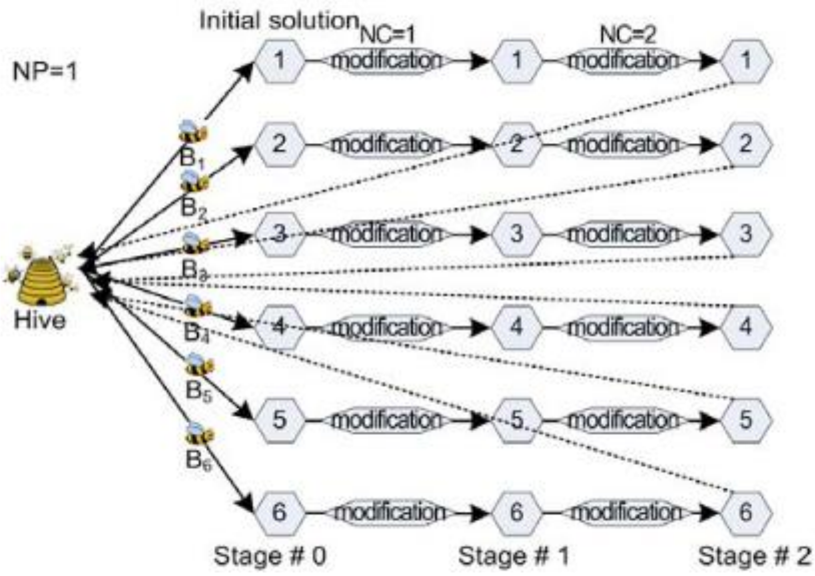

Fig. 1. The first forward and backward passes (NP=1)

Starting from the hive, bees first generate the initial solutions (Stage # 0). The initial resolution may be obtained during a random manner or by applying some famous heuristics. After that, all bees still fly through the created artificial network that consists of nominal variety of stages. every stage (one column of artificial nodes) contains the set of complete solutions generated by all bees engaged within the search method. In every new stage, each bee modifies its current resolution compared to the answer in previous stage. every stage consists of B possible solutions to the thought-about drawback. variety of changes (NC) at intervals one passing play may be per advance or may be indiscriminately chosen at the start of every passing play. once NC modifications of individual solutions are performed, the primary passing play is finished and also the backward pass begins [5,6,7,8,].

During backward pass, all bees come back to the hive (illustrated by dash lines in Fig.1) so as to share data and compare the standard of generated solutions. the standard of bee's resolution corresponds to the thought-about objective perform price. it's assumed that every artificial bee may be conscious of its own objective perform price and will acquire the data regarding solutions' quality generated by all alternative bees. throughout the backward pass, bees exchange data regarding the standard of singly generated solutions and begin to participate during a decision-making method. It means each bee decides whether or not it'll keep loyal to its current resolution or not. The bees with higher resolution quality (objective perform value) have additional probability to retain their solutions. Bees that are loyal to their solutions kind the set of recruiter bees, whereas alternative bees from the colony become uncommitted followers. Recruiter bees advertise their solutions making an attempt in such thanks to attract uncommitted followers to affix them throughout the accomplishment method. within the next passing play, every uncommitted follower should decide whether or not it'll still explore its own resolution, or to start out conjointly exploring one in all the solutions being publicized by the recruiter bees. it's assumed that solutions with higher qualities have bigger probability to be chosen by follower bees. The sets of recruiter bees and uncommitted followers are modified

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from one backward pass to a different. within the following (second) passing play, bees are absolving to build their next individual selections and to still explore the search house severally. as an example, allow us to assume that once scrutiny all generated solutions throughout the backward pass, bees B_2, B_3 and B_6 set to abandon from their solutions. allow us to conjointly assume that in accomplishment method uncommitted bee B_2 set to affix (first) recruiter bee B_5 and bee B_6 set to affix bee B_4, as illustrates Fig. 2.

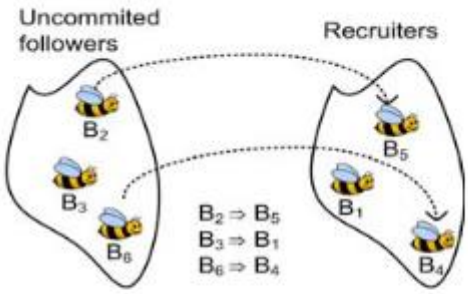

Fig. 2. Bees' recruitment process

In given example, bee B_2 can fly through the synthetic network on an equivalent path already generated by the bee B_5. It means the bee B_2 can take the answer of the bee B_5. within the same approach, B_6 can take the answer generated by bee B_4. The uncommitted followers B_3 in addition because the recruiter bee B_1 can keep already generated solutions and fly severally from alternative bees.

The delineate procedure continues within the same approach throughout the remainder forward passes. it's continual till the required variety of passes (NP) is performed throughout one formula iteration. At the tip of iteration, one or additional solutions are created. the most effective discovered resolution throughout the primary iteration is saved then the second iteration begins. The BCO formula runs iteration by iteration till a given stopping condition is met. At the tip of search method, the best-found resolution is reported because the final one.

BCO-WCP Algorithm

Following are the main steps of the planned BCO-WCP algorithm:

A. Resolution format

An initial complete resolution has got to be generated before the looking procedure starts. within the planned BCO-WCP algorithmic program, the initial resolution is generated in an exceedingly random manner. A random resolution that contains K wavelength converters is generated for every bee within the hive. The initial resolution may be additionally generated victimisation some known WCP heuristics.

B. Resolution modification

The main step of the BCO algorithmic program is modification of the answer through NP forward passes at intervals single iteration. because it has been already represented, throughout every passing game every bee changes its answers by creating NC modifications to the previous solution. just in case of BCO-WCP algorithmic program, every bee replaces NC wavelength

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convertor nodes in its previous answer [9,10]. the quantity of converters modified (NC) in every passing game is per advance. It may well be chosen because the pre-specified price between one and *K*. In such the simplest way, some nodes area unit off from this answer and new ones supported node utility price area unit additional. we tend to outline the node utility V_i, for every network node *i,* within the following way:

$$V_i = \frac{T_i}{\max_i T_i}, \; i = 1,2,\dots,N \tag{1}$$

where T_i is that the total transit traffic passing through node *i*. Nodes with higher values of transit traffic have larger utilities. supported nodes utilities, we tend to outline the probability P_i that the precise bee chooses node *i* to be enclosed during a changed (new) answer consistent with following equation:

$$P_i = \frac{V_i}{\sum_{j=1}^{J} V_j}, \; i = 1,2,\dots,N \tag{2}$$

where J is that the range of nodes not presently enclosed in an exceedingly answer. It may well be detected that node with bigger utility values have higher probability to be enclosed in an exceedingly new answer. victimization the wheel and a random range generator, every bee chooses new Tar Heel State nodes as candidates for convertor location and so new complete solutions are obtained.

C. Comparison of solutions

After new solutions are generated, all artificial bees are flying back to the hive to check the standard of their solutions. The comparison of solutions relies on objective perform price of individual solutions. just in case of BCO- WCP, the target perform is that the network block chance P_{block} that has got to be decreased. so as to make a decision that bee can keep its answer, we tend to use the chance that *b-th* bee, at the start of subsequent passing $s+1$, are loyal to its antecedental generated answer as follows:

$$P_b^{s+1} = e^{-\frac{O_{man} - O_b}{s}}, \; b = 1,2,\dots,B \tag{3}$$

Where:

O_b – denotes the normalized price of the target operate for resolution created by the *b-th* bee;

O_{max} – represents most overall normalized values of solutions to be compared;

s – standard range of step, i.e., forward/backward pass (s=1, 2, …, *NP*).

The normalized price of the target operates O_b for resolution created by the *b-th* bee is obtained as follows:

$$O_b = \frac{P_{block}^{max} - P_{block}^{b}}{P_{block}^{max} - P_{block}^{min}}, \; b = 1,2,\dots,B \tag{4}$$

where $P_{block}^{min}$and P_{block}^{max}ar lowest and peak values of block possibilities obtained by all engaged bees, severally, and $P_{block}^{b}$is that the block chance of the answer obtained by the *b-th* bee. allow us to comment in additional detail the previous equations. It may be seen from combining weight. (4) that if the block chance of the *b-th* bee answer P^{b}_{block} is nearer to the worst worth of all obtained solutions P^{max}_{block} then its normalized worth *Ob* is smaller and vice versa [9,10,11,12]. supported combining weight. (3), a lower *Ob* worth can decrease the probability that bee b is going to be loyal to its previous answer. In different words, the larger the worth of block chance obtained by answer of bee b, the smaller probability is that bee can keep any it's answer. in addition, the larger the standard variety of the pass, the upper the influence of the already discovered answer are going to be. this can be expressed by the term s within the divisor of the exponent. In different words, at the start of the search method, bees become braver to look the answer area. A lot of forward passes they create, the less the bees have courageousness to explore the answer area. A lot of we have a tendency to are approaching to the tip of the search method, a lot of targeted the bees are on the already discovered answer. exploitation the combining weight. (3) and a random variety generator, every artificial bee decides whether or not to become uncommitted follower or to continue with exploring its own answer. If chosen random variety is smaller than the calculated chance, then the bee stays loyal to its own answer. Otherwise, the bee b becomes uncommitted follower.

D. enlisting method

After the answer comparison is performed, assume that the bee b decides at the start of latest aerial to abandon from its resolution and to follow a number of the recruiter bees. inside the recruiting method, associate degree uncommitted bee decides what recruiter bee it'll follow, taking into consideration the standard of all publicized solutions.

The probability that b's resolution is going to be chosen by any uncommitted bee can be outlined as follows:

$$P_b = \frac{O_b}{\sum_{k=1}^{R} O_k}, \; b = 1,2,\dots,R \tag{5}$$

where:

O_k - represents the normalized price of the target perform of the k-th publicized resolution, and

R - denotes the quantity of recruiter bees.

Using the equivalent. (5) and a random variety generator, every uncommitted follower joins one recruiter bee employing a wheel technique. After that, the recruited bees fly at the side of their recruiters throughout future aerial on a similar path as antecedental discovered by the recruiter bee. during this approach, the bee that wishes to continue another bee's resolution can set its resolution specifically because the designated bee, however can continue the formula severally. At the tip of this path, all bees are liberated to severally search {the resolution the answer} area and generate future solution modification. It may be seen from equivalent. (4) that if a bee b has found the simplest resolution in step s, i.e., resolution with lowest blocking probability ($P^{b}_{block} = P^{min}_{block} \Rightarrow O_b = O_{max}$, see Eq. 3), then that bee can fly within the next aerial *s+1* on a similar path with the probability $P^{s+1}_{b} = 1$. the upper the blocking probability P^{b}_{block} the smaller is that the probability of flying once more on a similar path.

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The delineate procedure iterates through the pre-specified maximal variety of iterations. The best-found resolution obtained throughout iteration is employed as initial resolution for future iteration. If the optimum resolution of the WCP downside is known prior to, the iteration procedure finishes once the optimum resolution is found for the primary time, otherwise when the largest variety of iterations are performed. The total number of forward and backward passes (steps) from the start of search method till the simplest (optimal) resolution is found determines the potency of the formula.

Measure the performance

In order to gauge the performances of the planned BCO-WCP rule we've got administrated intensive simulation studies on 2 realistic optical WDM network examples, like the NSFNet (National Science Foundation Network) with fourteen nodes and EON (European Optical Network) with nineteen nodes, that area unit illustrated by Fig. 3. we tend to cantered our analysis on given network examples, as a result of their appropriate within the read of size and enough complexness to point out the benefits of application of the BCO-WCP rule and at identical time to permit America to perform a large variety of simulation experiments so as to check the validity of the rule. Moreover, for each mentioned network examples, we tend to were still able to realize the optimum resolution victimization the metallic element approach.

Conclusion

In this paper, BCO algorithmic rule tailored to unravel the WCP downside in wavelength routed optical networks is projected. The algorithmic rule finds the most effective locations of restricted range of WCs specified the network interference likelihood is reduced. to gauge the performances of the BCO-WCP algorithmic rule, we tend to tested it on realistic optical network topologies below completely different range of accessible converters and numerous traffic eventualities. it's been established that our algorithmic rule is capable to provide prime quality solutions (the same because the optimal). Moreover, the procedure quality of the algorithmic rule is sort of low considering that it's capable to search out answer inside tiny electronic equipment times. By increasing the matter quality, the number of steps till finding optimum answer is simply slightly multiplied. it's been shown that our algorithmic rule provides higher potency compared to similar alternative approaches, like American state and PSO metaheuristics. Simulation experiments show that the desired procedure (CPU) time extremely depends on the population size, range of forward/backward passes and range of iterations, that ar the input parameters of the BCO algorithmic rule. However, the solutions' quality can't be improved considerably by increasing the number of bees an excessive amount of. Hence, a comparatively tiny population of artificial bees ought to be wont to save the electronic equipment time. Simulation tests also are performed in additional complicated networks (e.g., few tens of nodes) and indicate smart performances, too. Generally, prime quality of solutions still as superior potency of the BCO-WCP algorithmic rule ensure that advised algorithmic rule is totally indispensable to be used for utilisation in realistic optical networks.

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